



Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) Publication number:

0 329 794
A1

(12)

EUROPEAN PATENT APPLICATION
published in accordance with Art.
158(3) EPC

(21) Application number: 88907385.4

(51) Int. Cl.⁴: G01N 33/53 , G01N 33/531 ,
G01N 33/577 , G01N 33/543

(22) Date of filing: 30.08.88

(66) International application number:
PCT/JP88/00861

(67) International publication number:
WO 89/02075 (09.03.89 89/06)

(30) Priority: 01.09.87 JP 216355/87

(43) Date of publication of application:
30.08.89 Bulletin 89/35

(84) Designated Contracting States:
AT BE CH DE FR GB IT LI NL SE

(71) Applicant: TEIJIN LIMITED
11 Minamihonmachi 1-chome Higashi-ku
Osaka-shi Osaka 541(JP)

(72) Inventor: 2OSODA, Kenji
3-12, Asahi-cho 3-chome Kawagoe-shi
Saitama 350(JP)

Inventor: HONDA, Hitomi
18-4, Tamadalra 3-chome Hino-shi
Tokyo 191(JP)

Inventor: KUBOTA, Takaaki
18-4, Tamadalra 3-chome Hino-shi
Tokyo 191(JP)

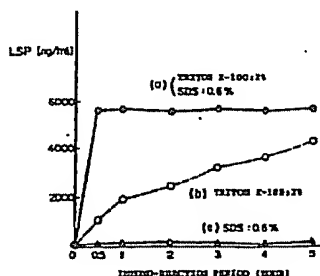
Inventor: SUZUKI, Hideaki
7-18, Sakuramachi 2-chome
Koganei-shi Tokyo 184(JP)

(74) Representative: Votier, Sidney David
CARPMAELS & RANSFORD 43, Bloomsbury
Square
London WC1A 2RA(GB)

(54) METHOD FOR ASSAYING HUMAN LUNG SURFACE ACTIVE SUBSTANCE.

(57) A method for assaying a human lung surface active substance in a specimen according to an immunological technique composed of antigen-antibody reaction, which comprises conducting the immuno-reaction in the presence of both an anionic surfactant and a nonionic surfactant in a buffer solution for the reaction.

FIG. 4



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Method of Quantitating Human Pulmonary Surfactant

Field of the Art

The present invention relates to a method for quantitating the human pulmonary surfactant with the use of monoclonal antibodies against the human pulmonary surfactant apoproteins.

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Background of the Art

In the alveoli of the lung of an animal, there exists a physiologically active substance which mainly comprises phospholipid and is called a pulmonary surfactant. While covering the inner walls of alveoli, this substance displays the activity to protect the alveolar epithelium and has an important physiological function for the animal to maintain its respiratory functions. More particularly, it is said that the pulmonary surfactant exerts a specific surface action to cause changes in the surface tension of the inner surfaces of alveoli in response to expiration and inspiration, thus contributing to the maintenance of stability among the alveoli and manifestation of the anti-atelectasis as well. The deficiency of such a pulmonary surfactant invites the collapse of the alveoli making them impossible to keep the stabilized ventilation and thus causing the idiopathic respiratory distress syndrome (IRDS) which is sometimes seen with newborns.

Means can be adopted to prevent a newborn from being born with such a syndrome: when the result of the determination of the pulmonary surfactant content in the amniotic fluid, which is correlated to the growth of the fetal lungs, shows that the fetus is going to be born with immature lungs, it is possible to exercise such intrauterine therapy for the fetus as augmentation of secretion of the pulmonary surfactant by administration of steroid.

As regards the methods of determining or estimating the content of pulmonary surfactant in the amniotic fluid, several methods have hitherto been proposed. For example, there are a method in which the L/C ratio (ratio between lecithin and sphingomyelin) in the amniotic fluid is determined and another method in which the amount of dipalmitoyl phosphatidyl choline (DPPC) in the amniotic fluid is measured as the marker of the pulmonary surfactant; however, the former has a demerit of presenting a low correlation with IRDS since the method does not determine the phospholipid content which is the main component of the pulmonary surfactant and the latter involves a problem of having a low sensitivity.

In adults, deficiency of the pulmonary surfactant causes symptoms such as adult respiratory distress syndrome (ARDS). The pulmonary surfactant in lung washing, for instance, DPPC or phosphatidyl glycerol (PG) as a marker for the surfactant, is determined for diagnosis of pulmonary diseases. The determination, however, encounters a problem of unsatisfactory sensitivity.

In the meantime, the lung washing is physicochemically measured, for example, to determine its surface tension. Sputum from patients is also used to make diagnosis, for example, by examining its viscosity and color tone or measuring fucose reflecting the amount of tracheal mucus in the sputum. Sputum can be collected easier than lung washing and this means the former is superior to the latter as a sample for measurement.

Incidentally, about 90% of the pulmonary surfactant is lipids such as phospholipid and neutral lipid and about 10% is protein. They exist as a complex of lipid and protein, i.e. as the lipoprotein. The removal of lipids from the pulmonary surfactant gives water-insoluble protein, which is called apoprotein (LSP) mainly composed of protein with a molecular weight of about 36,000 (36K). Since protein excels phospholipid in specificity and can be detected at higher sensitivity, studies have been made as to the use of protein as the marker of the pulmonary surfactant and immunological quantitation using polyclonal antibodies has also been attempted. However, problems are also found with the method, in which polyclonal antibodies are used, in that the determination procedure takes a long time and that the sensitivity is not enough.

To cope with such problems, the present inventors have already produced monoclonal antibodies against the apoproteins constituting the pulmonary surfactant and proposed a method for quantitating the pulmonary surfactant by use of the monoclonal antibodies [Japanese Patent Laid-open Specification No. 62-64956 (1987)]. Difference in reactivity has been found, however, between the standard sample of apoprotein and the pulmonary surfactant in the test samples such as amniotic fluid or sputum, when the immunological measurement was made, as stated above. This is because the pulmonary surfactant in the samples is composed of apoprotein and 10 times amount of phospholipid (in case of sputum, tracheal mucus is additionally included) and the immunoreactions are inhibited by these phospholipids and tracheal mucus. In order to overcome the problems, the immunological reaction must be continued for a long time and it is

inconvenient for diagnosis of urgent diseases such as IRDS or ARDS.

Disclosure of the Invention

5 Hereupon, the present inventors studied on the conditions for immunological measurement with two kinds of monoclonal antibodies and polyclonal antibodies which are specific to apoprotein, described in Japanese Patent Specification Laid-open No. 62-64956. As a result, they found that the apoprotein and the lipoprotein in the samples reached the same equivalent point in the immunological measurement in a short
10 time, in other words, the apoprotein in lipoproteins can be correctly captured, by selecting the surfactant to be added to the buffer solution for the immunoreactions, thus reached the present invention.

Namely, the present invention is a method for quantitating human pulmonary surfactant in samples on the basis of the immunological process including antigen-antibody reactions, which is characterized by conducting the immunoreactions in a buffer solution including anionic surfactants as well as nonionic ones.

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Brief illustration of drawings

Figure 1 shows the observed values of pulmonary surfactants (lipoproteins) in an amniotic fluid sample, when the concentration of SDS is varied in the buffer solution (2% Triton) for dilution of amniotic fluid samples (the immunoreactions were conducted at 37 °C for 1 hour).
20

Figure 2 shows the observed values of pulmonary surfactants (lipoproteins) in an amniotic fluid sample, when the concentration of SDS is varied in the buffer solution (1% Triton) for dilution of amniotic fluid samples (the immunoreactions were conducted at 37 °C for 1 hour).

25 Figure 3 shows the observed values of pulmonary surfactants (lipoproteins) in an amniotic fluid sample, when the concentration of SDS is varied in the buffer solution (2% Triton) for dilution of amniotic fluid samples (the immunoreactions were conducted at 37 °C for 30 minutes).

Figure 4 gives change of the observed values of pulmonary surfactant (lipoproteins) in amniotic fluid with the passage of time during the immunoreactions.

30 Figure 5 gives the observed values of pulmonary surfactant in a sputum sample, when the concentrations of SDS and Triton are varied.

Figure 6 gives the amounts of pulmonary surfactant (LSP) from patients with chronic respiratory diseases and bronchoalveolar epithelial cancer and LSP/lucose ratios.

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The Best embodiment of the invention

It has been made possible to carry out solid-phase immunoreactions in a short time according to the present invention. The reasons may be cited as follows: when only nonionic surfactant is employed, there is
40 no adverse effect on the immunoreaction, but the surface-activating effect is unsatisfactory. In the meantime, the use of only anionic surfactant results in powerful surface-activating effect, but in inhibition of the antigen-antibody reactions, as the protein of the antigen is denatured. The combination of anionic and nonionic surfactants manifests, however, the merits of both surfactants, powerful surface activation due to anionic surfactant and protein protection due to nonionic surfactant, to make it possible to shorten the time
45 of immunoreactions.

In the present invention, samples mean human amniotic fluid, sputum, lung washing and the like.

There is no particular limit in the immunological method according to the present invention, and either polyclonal or monoclonal antibodies against the apoprotein of pulmonary surfactant can be used as an antibody in the antigen-antibody reactions. These antibodies can be produced by known methods.

50 As the surface active agent which is used in the present invention, are cited nonionic agents such as polyoxyethylene alkyl ethers, polyoxyethylene fatty acid (mono)esters, polyoxyethylene alkyl thioethers and anionic agents such as higher alcohol sulfate ester, alkylsulfonate salts, alkylbenzenesulfonate salts, dinaphthylmethanedisulfonate salts, alkylsulfosuccinate salts, polyoxyethylene alkyl ether sulfate ester, polyoxyethylene alkylphenol sulfate ester or the like. A polyoxyethylene alkylphenol ether, for example, Triton (the trade name of a product manufactured by Rohm & Haas Co.) is preferred as the nonionic
55 surfactant, while an alkylsulfonate salt, for example, sodium dodecylsulfate (SDS), as the anionic one. The concentrations are preferably about 0.25 to 4% by weight in the former and about 0.2 to 3% by weight in the latter, and the ratio of the concentrations in weight basis is particularly preferred to be 1.0 to 4.0. Less

than 1.0 of Triton/SDS concentration ratio shows a tendency to inhibit the antigen-antibody reactions by protein denaturation of the antibodies, as SDS with powerful surface-activating effect predominates. In the meantime, over 4.0 reveals prominent protein-protecting effect by the nonionic surfactant to mask the effect of the anionic surfactant to disperse or loosen the phospholipids and respiratory mucus surrounding the apoprotein.

According to the present invention, the primary antibody is preferably immobilized on a support and the immobilization can be done by a known method. The support is solid and balls, beads, gears and microplates from polystyrene, polyethylene, polyacrylates, teflon, polyacetal or the like are preferably used as the support.

No limit is placed upon the method and procedure of labeling and the method and procedure of detecting. Any known methods and procedures such as determination by the secondary reactions with anti-immunoglobulin antibody labeled with a radioactive substance, enzyme or fluorescent material, or with Staphylococcus protein A may be adopted. As the labeling agents, such enzymes as horseradish peroxidase, β -D-galactosidase or alkaline phosphatase are used in the enzyme immunoassay (EIA), 251 I and 3 H in the radioimmunoassay (RIA), and fluorescein-isothiocyanate in the fluorescence immunoassay (FIA) in general; however, other labeling agents may also be used so far as their activity is assayable.

In case where the labeling agent is an enzyme, a substrate is used for assaying its activity. As the substrate, 2,2'-azinodi-[3-ethylbenzthiazoline sulfonic acid]ammonium acid (ABTS)-H₂O₂, 5-aminosalicylic acid-H₂O₂, o-phenylenediamine-H₂O₂ and 4-aminoantipyrine-H₂O₂ may be used as the substrate for horseradish peroxidase, and fluorescein-di-(β -D-galactopyranoside) o-nitrophenol- β -D-galactopyranoside for β -D-galactosidase. In the assays, other reagents such as solubilizer, detergents and reaction terminator are additionally used.

The methods provided by the present invention is expected to offer a useful method for quantitating the apoproteins contained in the pulmonary surfactant in samples with ease in a short time for diagnosis of diseases of urgent like IRDS or ARDS.

The following examples illustrate the present invention.
% in the examples stands for % by weight.

Example 1

(1) After polystyrene beads were thoroughly washed, they were placed in a PBS (pH 7.4) solution containing monoclonal antibody PC 6 at the concentration of 20 μ g/ml and left at 4°C overnight. Thereafter, the beads were washed in a PBS solution and then left standing in 0.5% bovine serum albumin (BSA) aqueous solution at 4°C overnight for postcoating treatment to give beads of insolubilized monoclonal antibodies.

(2) Preparation of horseradish peroxide-labeled monoclonal antibodies

50 ml of dimethylformamide solution containing N-(m-maleimide benzoic acid)-N-succinimide ester (MBS) (10 mg/ml) was added to a PBS solution containing monoclonal antibody PE10 (1.0 mg/ml) and the reaction was conducted at 25°C for 30 minutes. The reaction mixture was then subjected to gel filtration with 0.1M phosphate buffer (pH 6.0) by use of a column filled with Sephadex G-25 to separate maleimidic monoclonal antibodies from unreacted MBS.

Besides the above procedure, an ethanol solution of N-succinimidyl-3-(3-pyridylthio)propionate (SPOP) (10 mg/ml) was added to a PBS solution containing horseradish peroxidase (HRP) (1.0 mg/ml) and the mixture was allowed to go through the reaction at 25°C for 30 minutes. Then, the reaction mixture was purified by filtration with 0.01M acetate buffer (pH 4.5) by use of a Sephadex G25 column and the fractions containing dithiopyridyl group substituted HRP were collected and concentrated approximately to about one-tenth of the original volume in a collodion bag on the ice bath. Then, 1 ml of 0.1M acetate buffer (pH 4.5) containing 0.85% NaCl and 0.1 M dithiothreitol was added thereto and the mixture was stirred at 25°C for 30 minutes to reduce the pyridyldisulfide groups introduced into HRP molecules. The reaction mixture was then subjected to gel filtration by Sephadex G-25 column to obtain fractions containing mercaptosuccinyl HRP.

The maleimidic monoclonal antibodies and the mercaptosuccinyl HRP obtained in the above were mixed and concentrated to 4 mg of protein concentration in a collodion bag on the ice bath. The concentrate was left standing at 4°C overnight and filtered on a column of ultrogel Aca44 to obtain HRP-

labeled monoclonal antibodies.

(3) Quantitation of pulmonary surfactant in amniotic fluid by change of SDS concentration (immunoreaction temperature: 37 °C)

As a buffer for diluting the amniotic fluid samples, mixtures of 2.0% Triton X-100 with SDS solutions of prescribed concentrations (0, 0.25, 0.5, 0.75, 1.0, 2.0, 3.0 and 4.0%) were used. These mixed solutions containing the amniotic fluid samples and a diluted solution containing monoclonal antibodies, PE 10 labeled with HRP, 200 µl each, were added to balls bearing monoclonal antibody PC6 in test tubes to effect immunoreactions at 37 °C for 1 hour. The solutions in the test tubes were sucked off, the remaining balls were washed with physiological saline solution. Then, a 3/7 (V/V) mixture of a methanol solution containing 1% 3,3',5,5'-tetramethylbenzidine/1M phosphate-citrate buffer (pH 4.5) containing 0.015% hydrogen peroxide was added to the test tubes, 0.4 ml each, and incubated at room temperature for 15 minutes. Then, 2 ml of 1.5N aqueous sulfuric acid solution was added to the test tubes respectively to stop the enzymatic reactions. The absorbance of each solution was measured using a spectrophotometer at a wave-length of 450 nm.

In the meantime, a calibration curve corresponding to individual concentrations of SDS was drawn using apoprotein as a standard substance, and the mixed solutions described above, as buffer solutions for dilution of amniotic fluid samples. The concentration of apoprotein (LSP) was determined from the absorbance at 450 nm wave-length using the calibration curve corresponding to SDS concentrations. The concentrations corresponding to individual SDS concentrations are shown in Figure 1.

As apparent from Figure 1, the antigen in the amniotic fluid samples (LSP) is recognized by the antibody relatively well in the range of SDS concentrations from 0.25 to 3.0 % in the presence of 2% Triton.

Example 2

Quantitation of pulmonary surfactant in amniotic fluid samples by change in concentration of Triton buffer (immunoreaction: 37 °C)

The same experiment as in Example 1 (3) was made except that mixed solutions of 1% SDS and Triton X-100 buffer varied in concentrations (0, 0.25, 0.5, 1.0, 2.0, 3.0, 4.0 and 5.0%) were used for sample dilution. The relationship between the concentrations of Triton and LSP values is shown in Figure 2. As apparent from Figure 2, the antigen in the amniotic fluid samples can be assayed relatively well in the range of Triton concentrations from 0.25 to 4.0% in the presence of 1% SDS.

Example 3

Quantitation of pulmonary surfactant in amniotic fluid samples by change of SDS concentrations (immunoreaction: 45 °C)

The same experiment as in Example 1 (3) was made except that mixed solutions of 2% Triton X-100 buffer and SDS solutions of varied concentrations (0, 0.2, 0.4, 0.6, 0.8, 1.0%) were used for sample dilution and the immunoreactions were carried out at 45 °C for 30 minutes. The relationship between SDS concentrations and LSP values is given in Figure 3. It is evident from Figure 3 that good results were obtained at 45 °C in the range of SDS concentrations from 0.2 to 1.0% in the presence of 2% Triton and 0.6% SDS attained the maximum immunoreaction.

Example 4

The influence of immunoreaction time on the observed values of pulmonary surfactants in amniotic fluid samples (immunoreaction temperature : 45 °C)

The standard substance (apoprotein), three kinds of buffer solutions for diluting amniotic fluid samples, (a) a mixture of 2% Triton X-100 and 0.6% SDS, (b) 2% Triton X-100 only, and (c) 0.6% SDS only, were used to conduct immunoreactions at 45°C varying the reaction time, 30 minutes, 1 hour, 2 hours, 3 hours, 4 hours and 5 hours, as in Example 1 (3). The concentrations of pulmonary surfactant in amniotic fluid were read from the calibration curves respectively at the prescribed times of immunoreaction and plotted on Figure 4.

Figure 2 shows that (c) 0.6% SDS only could not proceed the immunoreaction at all and (b) 2% Triton only retarded the reaction. On the contrary, (a) Triton/SDS mixed solution allowed the observed values to reach its equilibrium point in 30 minutes and the effect of the mixed solution is definitely evident.

Example 5

Monoclonal antibody PC6 and labeled monoclonal antibody PE 10 which were prepared in Example 1 were used to determine pulmonary surfactant in sputum samples by changes of both SDS and Triton concentrations.

Sputum was doubled in volume with physiological saline solution and homogenized. Solutions of 0, 0.5, 1.0, 1.5 and 2.0% SDS concentrations were individually combined with solutions of 0, 1, 2, 3 and 4% Triton concentrations respectively to prepare 25 kinds of mixed solutions. Then, the sputum sample diluted with physiological saline solution was diluted 10 times with these 25 kinds of solutions.

These mixture containing the sample to be determined and a diluted solution containing monoclonal antibody PE 10 labeled with HRP were added, 200 µl each, to balls having monoclonal antibody PC6 immobilized thereon in test tubes to conduct immunoreactions at 37°C for 1 hour. Then, the solution was sucked off from the test tubes, the remainings were washed with physiological saline solution and combined with a 3 : 7 (V/V) mixture of methanol solution containing 1% 3,3',5,5'-tetramethylbenzidine and 1M phosphate-citrate buffer solution (pH 4.5) containing 0.015% hydrogen peroxide, 0.4 ml in each test tube. After incubation at room temperature for 15 minutes, 2 ml of 1.5N aqueous sulfuric acid was added to each test tube to stop the enzymatic reactions. Then, the absorbance of each solution was measured using spectrophotometer at a wavelength of 450 nm. Absorbances corresponding to individual concentration ratios of Triton/SDS are shown in Figure 5.

Figure 5 shows that the antigen in sputum (LSP) is well recognized by the antigen in the range of concentration ratios from 1.0 to 4.0 (w/w).

Example 6

Quantitation of pulmonary surfactant in sputum sampling by changes of SDS and Triton concentrations using the latex agglutination method.

25 kinds of Triton/SDS solution mixtures were mixed with an equal amount (50 µl) of sputum respectively so that the final concentrations are adjusted to SDS 0, 0.5, 1, 1.5, and 2% and Triton 0, 1, 2, 3 and 4%. A latex emulsion bearing PC6 and PE10 on their surface, which recognize the apoprotein in pulmonary surfactant, (100 µl) was added to 100 µl of the Triton/SDS mixed solutions containing diluted sputums. After light stirring for 15 minutes, agglutination grades of the mixtures were recorded with symbols: -, ±, + and ++. The results are given in Table 1:

Table 1

| Triton/STD | 0 | 0.5 | 1.0 | 2.0 | 3.0 | 4.0 |
|------------|---|-----|-----|-----|-----|-----|
| | - | - | + | ++ | ++ | ± |

Example 7

Measurement of pulmonary surfactant in sputum

LSP/fucose concentration ratios were determined on individual samples from patients with membranous respiratory diseases (n = 17) and with bronchoalveolar epithelial cancer (n = 3) according to the conditions in Example 5 (Triton 3.0% and SDS 1%) and the values classified into the two groups are given in Figure 6.

As apparent from Figure 6, the sputum from patients with bronchoalveolar epithelial cancer has higher LSP/fucose ratio than mucous sputum (MS) and puriform sputum (PS) from patients with chronic respiratory diseases. It evidently shows that the method according to the present invention can be used for the differential diagnosis.

In the figure, MS stands for mucous sputum and PS, for puriform sputum from patients with chronic respiratory diseases, while BAC means the sputum from patients with bronchoalveolar epithelial cancer.

Claims

1. A method for quantitating human pulmonary surfactant according to the immunological method based on antigen-antibody reactions wherein the immunoreactions are conducted in a buffer solution containing a combination of anionic surfactant and nonionic surfactant.
2. A method for quantitating human pulmonary surfactant according to claim 1 wherein said apoprotein is determined using, as the antibodies, the first monoclonal antibody which recognizes the apoprotein of human pulmonary surfactant and the second labeled monoclonal antibody which also recognizes said apoprotein, but bonds to a different site in the antigen from that to which the first antibody bonds.
3. A method for quantitating human pulmonary surfactant according to claim 1 wherein said apoprotein is determined by conducting the immunoreaction using latex particles to which antibodies recognizing the apoprotein of human pulmonary surfactant are bonded.
4. A method for quantitating human pulmonary surfactant according to claim 1 wherein said anionic surfactant is an alkylsulfonate salt.
5. A method of for quantitating human pulmonary surfactant according to claim 1 wherein said nonionic surfactant is a polyoxyethylene alkylphenol ether.
6. A method for quantitating human pulmonary surfactant wherein said anionic surfactant is an alkylsulfonate salt, said nonionic surfactant is a polyoxyethylene alkylphenol ether, and the concentration ratio of nonionic surfactant to anionic surfactant is 1.0 to 4.0 by weight.

FIG. 1

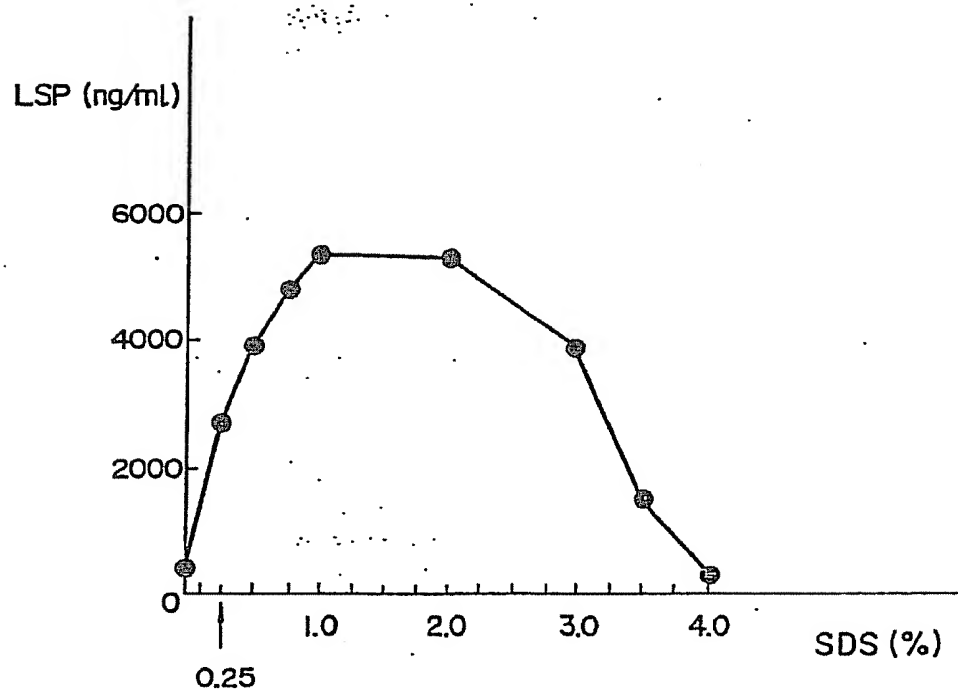


FIG. 2

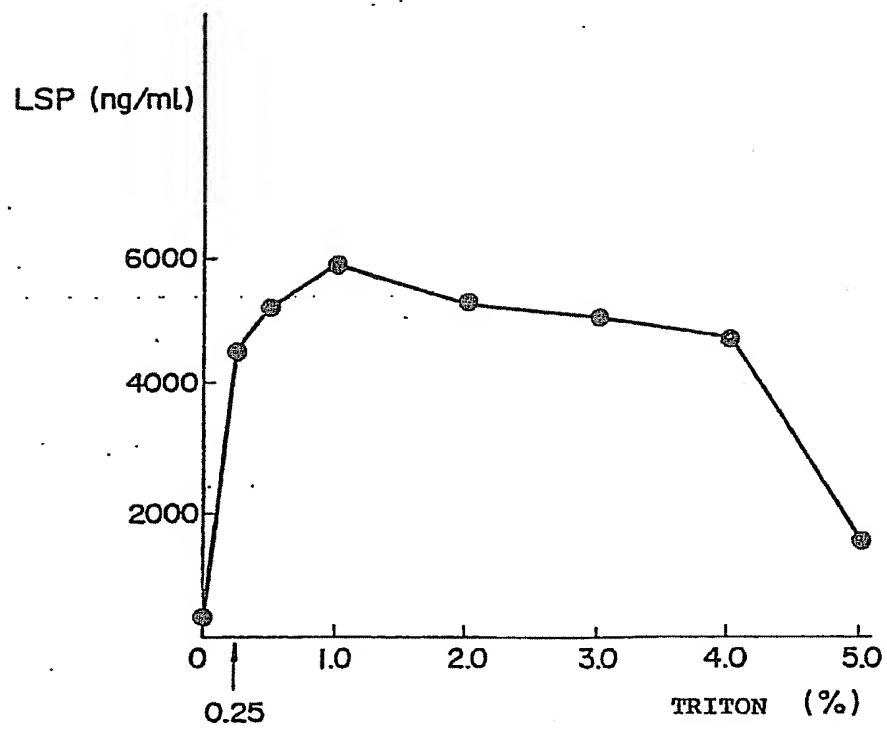
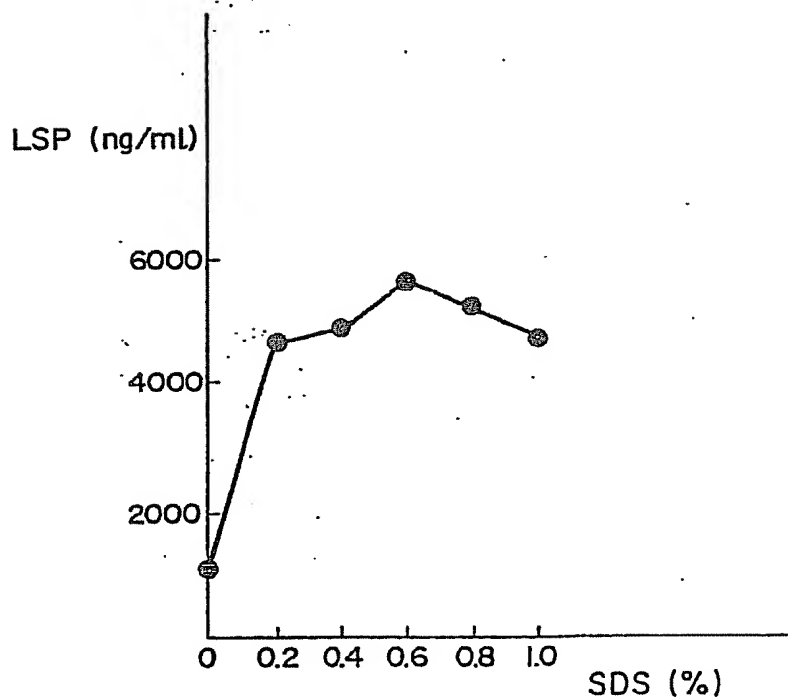


FIG. 3



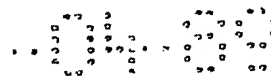
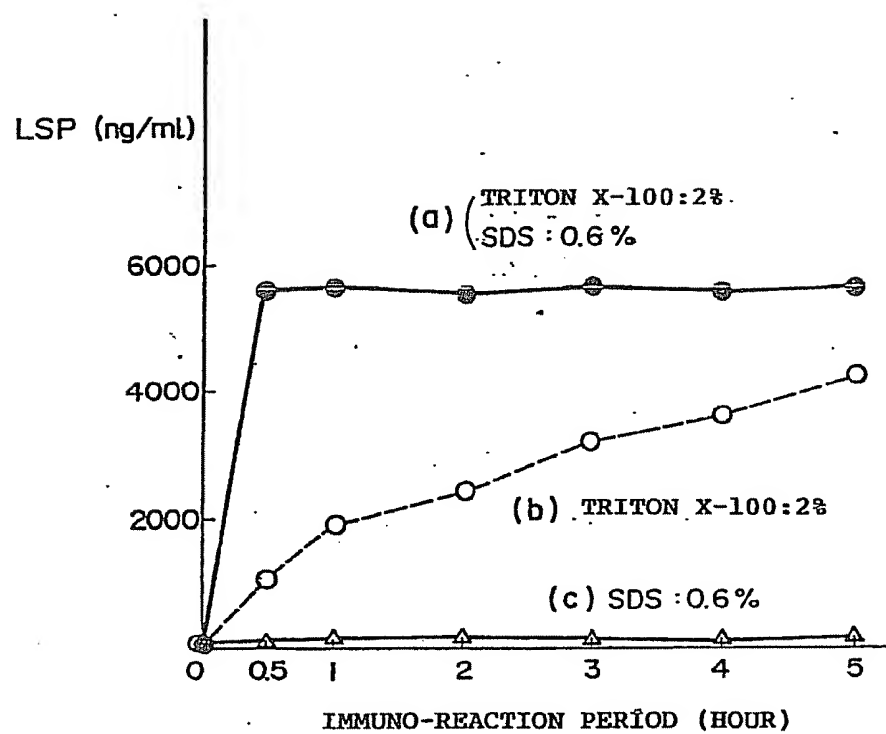


FIG. 4



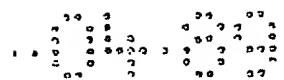
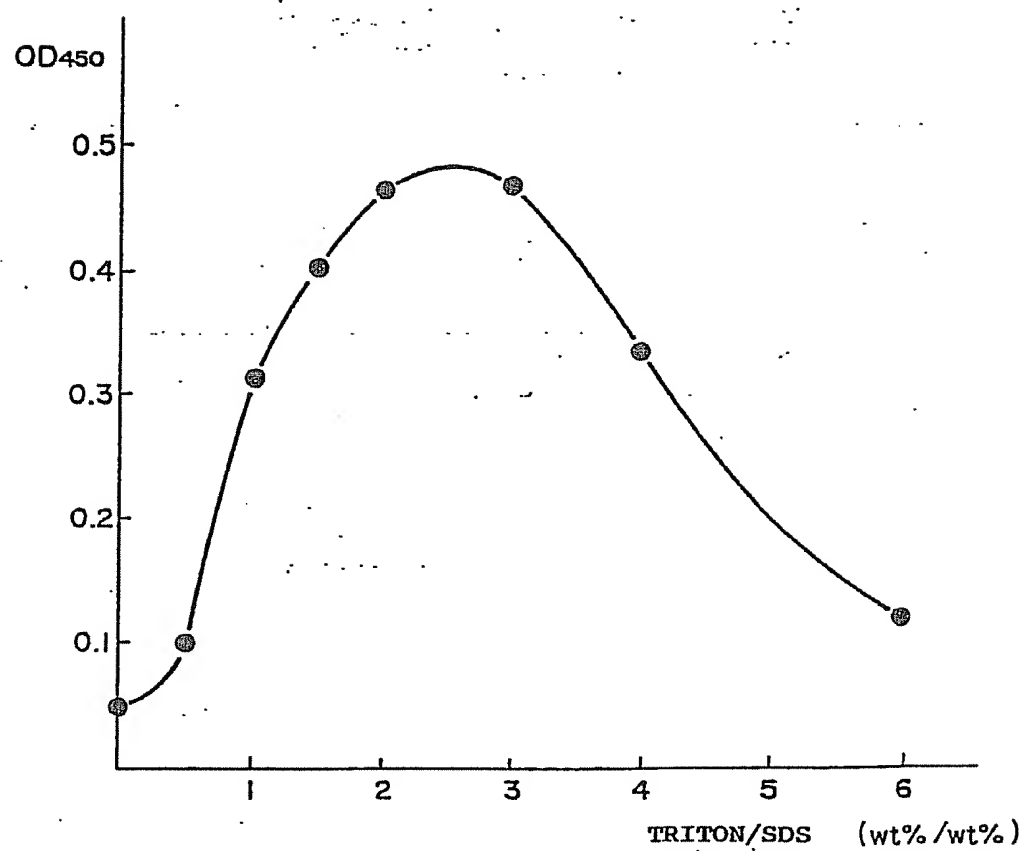


FIG. 5



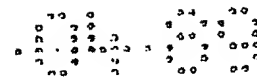
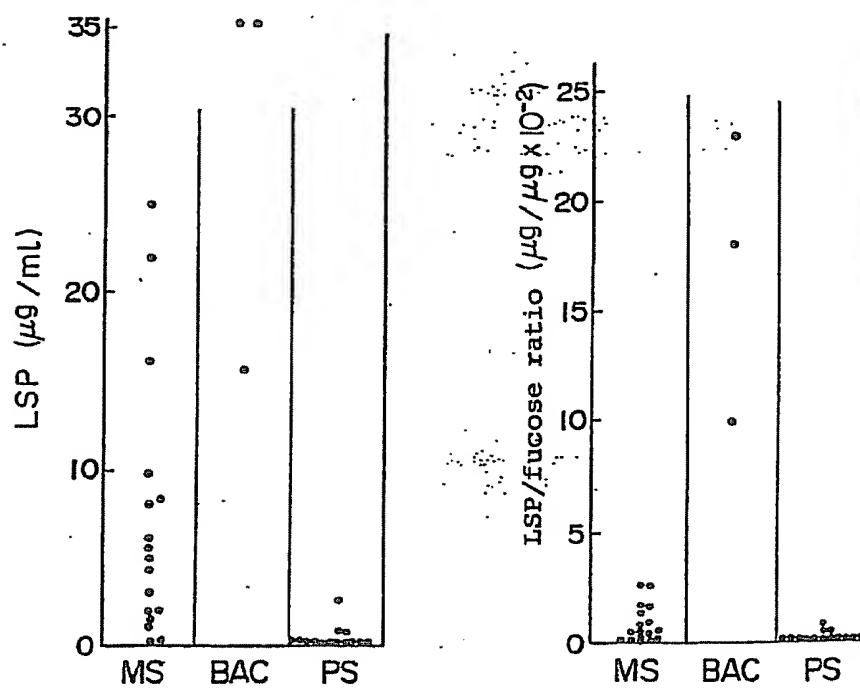


FIG. 6



INTERNATIONAL SEARCH REPORT

International Application No PCT/JP 88/00861

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|--|--|---|
| I. CLASSIFICATION OF SUBJECT MATTER (If several classification symbols apply, indicate all) * | | |
| According to International Patent Classification (IPC) or to both National Classification and IPC | | |
| Int. Cl ⁴ G01N33/53, G01N33/531, G01N33/577 G01N33/543 | | |
| II. FIELDS SEARCHED | | |
| Minimum Documentation Searched ¹ | | |
| Classification System | Classification Symbols | |
| IPC | G01N33/53, G01N33/531, G01N33/577 G01N33/543 | |
| Documentation Searched other than Minimum Documentation to the extent that such Documents are included in the Fields Searched * | | |
| Jitsuyo Shinan Koho 1971 - 1988 Kokai Jitsuyo Shinan Koho 1971 - 1988 | | |
| III. DOCUMENTS CONSIDERED TO BE RELEVANT ¹ | | |
| Category ² | Citation of Document, ¹¹ with indication, where appropriate, of the relevant passages ¹² | Relevant to Claim No. ¹³ |
| Y | JP, A, 61-275654 (Teijin Ltd.) 5 December 1986 (05. 12. 86) (Family : none) | 1-6 |
| Y | JP, A, 62-64956 (Teijin Ltd.) 24 March 1987 (24. 03. 87) (Family : none) | 1-6 |
| Y | JP, A, 61-277699 (Teijin Ltd.) 8 December 1986 (08. 12. 86) (Family : none) | 1-6 |
| Y | JP, A, 61-277700 (Teijin Ltd.) 8 December 1986 (08. 12. 86) (Family : none) | 1-6 |
| Y | JP, A, 58-187862 (Sanyo Chemical Industries, Ltd.) 2 November 1983 (02. 11. 83) (Family : none) | 1-6 |
| Y | JP, A, 59-97057 (Kainosu Kabushiki Kaisha) 4 June 1984 (04. 06. 84) (Family : none) | 1-6 |
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| IV. CERTIFICATION | | |
| Date of the Actual Completion of the International Search | | Date of Mailing of this International Search Report |
| October 12, 1988 (12. 10. 88) | | October 24, 1988 (24. 10. 88) |
| International Searching Authority | | Signature of Authorized Officer |
| Japanese Patent Office | | |